

# Modern Concepts of Cardiovascular Disease

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## SURGICAL CONSIDERATIONS OF ACQUIRED DISEASES OF THE AORTA AND MAJOR PERIPHERAL ARTERIES\*†

### III. Atherosclerotic Occlusive Vascular Disease\*\*

The atherosclerotic lesion, consisting of an atheroma with or without superimposed thrombus, produces arterial obstruction and arterial insufficiency of the part distal to the occlusion. These lesions involve the origin or bifurcation of arteries in certain characteristic locations, resulting in a variety of well-known clinical entities of arterial insufficiency. Regardless of the location of the lesion, it is now established that the lesion is frequently well localized and segmental in nature, with a relatively normal patent lumen proximal and distal to the occlusive process. This concept has led to the therapy of direct attack on the occlusive lesion, aimed at restoration of normal circulation through the main arterial channel. To achieve this objective, 3 basic types of surgical procedure have been developed, namely, thromboendarterectomy, excision and graft replacement, and graft bypass. The selection of patients for operation and the application of these direct surgical technics depend, in large measure, upon the nature and location of the lesion.

#### Aorto-Iliac Occlusions

Although this form of occlusive disease (also termed insidious thrombosis of the aorta, chronic aorto-iliac thrombosis, or Leriche's syndrome) may be quite variable in its pathologic features, it tends to assume certain recognizable patterns, suggesting classification into 2 groups: incomplete and complete aortic occlusion. In the former, extensive atheromatous mural changes occur in the common iliac arteries, apparently originating at the iliac or aortic bifurcations with progressive diminution in these changes, both proximally and distally. Subsequent enlargement of this atheromatous process causes increasing

narrowing of the lumen until a critical degree of constriction is reached which slows blood flow sufficiently to cause thrombosis, thus resulting in complete obstruction. Depending upon the progress and stage of development of these pathologic changes, there may be incomplete occlusion of both common iliac arteries or complete occlusion of one with partial involvement of the other. When, however, both common iliac arteries are similarly involved with intraluminal obstruction, complete occlusion of the terminal aorta occurs and gradual propagation of the thrombotic process takes place proximally toward the renal arteries. Ultimately, this may produce occlusion of these vessels with terminal renal failure. Analysis of our cases suggests that the obliterative lesion in patients with complete aortic occlusion tends to be well localized to the terminal aorta and bifurcation, whereas among those with incomplete occlusion there is a greater frequency of associated segmental occlusion in the peripheral arterial bed, particularly the superficial femoral artery. Although the disease tends to assume one of the characteristic patterns described above, there are some variations and even combinations of these different types. For this reason, and in order to apply effective therapy, it is essential to determine precisely the location and extent of the occlusive process by means of arteriography.

The disease occurs predominantly in the male

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\*\* Parts I and II of this article, concerned with aortic aneurysms and dissecting aneurysms of the aorta, were published in the October and November, 1959, issues.

sex; the ratio of males to females in our series was 10 to 1. Approximately 90 per cent of the cases occur in the fifth to seventh decades of life. The youngest patient in our series was 23 years of age and the eldest 83 years.

Clinical manifestations of the disease vary with the location, extent, and duration of the occlusive process. The earliest and most common complaint is intermittent claudication, not only in the legs but also in the thighs, hips, and buttocks. As the disease progresses, more severe manifestations of arterial insufficiency become apparent, and ultimately ischemic changes that are pregangrenous or associated with gangrenous lesions may take place in the feet. Particularly noteworthy are certain differences in the characteristic clinical manifestations of patients with aorto-iliac occlusion and those with femoral or peripheral occlusive disease. For one thing, pain in the hips, thighs, and buttocks constitutes the prominent complaint in the former group and often precedes the development of symptoms in the lower legs. For another, there is relative absence of significant trophic or nutritional changes in the legs and feet in the former group, in contrast with the frequency of such findings in the more peripheral occlusive lesions. Still another feature encountered in the majority of patients with aorto-iliac occlusion is the presence of a fairly well localized, soft, blowing systolic murmur usually heard best over the upper abdomen. Sexual impotence and hypertension are also more likely to occur in patients with complete aortic occlusion. The most significant physical finding is the absence or diminution of pulses in the femoral, popliteal, and pedal regions.

Although the diagnosis can usually be made on the bases of the characteristic clinical manifestations, angiography is an important method of study, not only because it establishes the diagnosis, but also because it provides precise information concerning the location of the occlusive lesion and its extent, both proximally and distally, which is essential for proper therapy. This is done by injection of small doses (30 ml. or less) of 85 per cent Hypaque solution into the aorta opposite the twelfth lumbar vertebra. By using special equipment, roentgenographic visualization of the entire arterial bed from this level to well below the knee may be obtained. The importance of this method of study is illustrated by the fact that segmental occlusive lesions in the superficial femoral artery, although not clinically apparent, were demonstrated in about one-fifth of the cases with aorto-iliac occlusion. Operative correction of both lesions at the same operation permitted effective restoration of circulation and prevented recurrence of symptoms.

Since the occlusive process in the aorto-iliac region is almost always segmental in nature with

a patent distal vessel in the pelvis, groin, or popliteal region, virtually all cases may be considered candidates for operation. Advanced cerebral, cardiac, or malignant disease, as well as any other conditions which severely limit both activity and life expectancy, constitute the main contraindications to operation unless the alternative is amputation. Under these circumstances, a restorative operation is substituted for amputation. Advanced age, compensated heart disease, hypertension, and diabetes are definitely not contraindications to operation. This is evident by the fact that in our series of patients almost one-half had hypertension, one-third had heart disease, and about one-tenth had diabetes. Regardless of these complicating factors, the total mortality was only 2.5 per cent.

Treatment is directed toward restoration of normal circulation in the main arterial channel. To achieve this objective, 3 basic types of operative procedure may be employed, namely, thromboendarterectomy, excision with graft replacement, and the bypass graft. The indication for each of these procedures, or their combination, is dependent upon the location, extent, and nature of the occlusive lesion. Thromboendarterectomy, for example, may be applied in cases in which there is a well-localized occlusive process with minimal medial and adventitial mural involvement. In some cases with more extensive and destructive mural arteriosclerotic changes, but in which the occlusive process is well localized, excision of the diseased segment with graft replacement may be more suitable. In other cases, with more extensive occlusive disease involving longer vascular segments, and particularly in older patients, the bypass graft procedure is considered preferable. In still other cases, it may be necessary to combine these procedures.

Highly gratifying results have been provided by these methods of treatment, as evidenced by analysis of our cases. Thus, successful results, as indicated by the restoration of pulses, as well as the relief of symptoms, were obtained in 96 per cent of the cases. Particularly noteworthy is the fact that equally successful results were obtained by the various surgical procedures employed, thus supporting our conviction that each of these methods of surgical treatment is most effective when employed in accordance with proper circumstances (Table I). Despite the frequency of hypertension, heart disease, and advanced age, the total operative mortality was relatively low. Follow-up studies on these patients, extending for periods over 5 years, have also been most gratifying. Recurrent occlusion was encountered in only 27 patients in this series. Of particular significance, however, is the fact that in all of these patients but one, who refused operation, successful restoration of circulation was achieved by a second operative procedure

**Table I***Aorto-Iliac Occlusions — Results of Treatment*

Procedure	No. of Cases	Successful		Deaths	
		No.	%	No.	%
Excision and graft replacement	148	141	95	4	2.7
Endarterectomy	121	116	96	3	2.5
Excision and graft replacement with bypass	161	153	95	7	4.3
Bypass only	208	201	97	2	1.0
Total	638	611	96	16	2.5

in which a bypass graft was employed (Table II).

**Femoro-Popliteal Occlusions**

The occlusive process occurring in the femoro-popliteal region may be quite discrete and well localized, with normal arterial lumens above and below the obstruction. In others, the ob-

**Table II***Aorto-Iliac and Femoro-Popliteal Occlusions  
Recurrent Occlusion and Reoperation*

Type	No. of Cases	Recurrent Occlusion		
		No. of Cases	Reoperation	
			Cases	Successful
Aorto-iliac	638	27	26	26
Femoro-popliteal	583	96	75	66
Total	1221	123	101	92

literative lesion is much more extensive, with involvement of a considerable portion, if not most, of the superficial femoral artery, but with patency of the popliteal artery and distal arterial bed. In still other cases, the occlusive process may be diffuse, extending well down into the small vessels of the calf and foot not associated with a distal segment of sufficient size to permit attachment of a graft. Although intermittent claudication limited to the calf and foot may be the chief symptom, severe peripheral ischemia is more likely to occur with occlusions at the latter level because of the frequency of diffuse lesions. The extent of the lesion, however, cannot be de-

termined on clinical grounds; consequently, arterial visualization is necessary for accurate localization of the lesion. Femoral arteriography may be adequate for this purpose in some cases, but owing to the frequency of unsuspected proximal partial occlusions of the aorto-iliac region, we now believe that it is preferable to obtain roentgenographic visualization of the abdominal aorta, iliac, femoral, and popliteal arteries in most patients with femoral occlusions. Progression of proximal occlusions, producing retardation of blood flow through grafts inserted in the femoro-popliteal segment, has been the cause of recurrent occlusion in about one-third of these cases. Complete restoration of circulation is therefore necessary for relief of symptoms and prevention of recurrent occlusion.

Patent distal segments favorable for operation have been found in approximately 90 per cent of patients with good circulation at rest and in about 50 per cent of patients with the more advanced manifestations of arterial insufficiency. During the past 5 years, using these criteria of operability, 583 cases with occlusions of the femoral and popliteal arteries have been submitted to operation. The age distribution and the frequency of hypertension and heart disease in these patients were essentially the same as in those with aorto-iliac lesions. The occlusion was bilateral in 27 per cent.

Treatment in this group of patients, as in those with the more proximal lesions, was directed toward restoration of normal distal pulsatile circulation. To achieve this objective, the same basic procedures previously described were employed, but not with the same frequency. The occlusion was well localized to a short segment suitable for endarterectomy in only 25 cases (4 per cent). Excision and graft replacement was performed in 19 cases (3 per cent) early in the series, but due to certain disadvantages associated with interference of collateral circulation, this procedure has not been employed for femoro-popliteal occlusions during the past 3 years, except in cases in which there was an associated aneurysm of the femoral or popliteal artery. The bypass graft procedure does not alter blood flow in the patient's own vessels, and the entire diseased segment may be bypassed without significantly extending the operation. For these reasons, this procedure is considered the operation of choice, and it was employed in the treatment of 539 cases.

Using these methods in accordance with these indications, excellent results with restoration of a normal distal pulsatile blood flow and complete relief of symptoms of arterial insufficiency have been obtained in a high proportion of patients (Table III). In the follow-up studies of these patients, extending for periods over 5 years, recurrent obstruction was encountered in 96 patients (Table II). This was due to pro-

**Table III**  
*Femoro-Popliteal Occlusions*  
*Results of Treatment*

Procedure	No. of Cases	Successful		Deaths	
		No.	%	No.	%
Endarterectomy	25 ( 4%)	16	64	0	0
Excision and graft replacement	19 ( 3%)	16	84	0	0
Bypass	539 ( 93%)	479	89	3	0.6
Total	583 (100%)	511	88	3	0.5

gression of proximal lesions in the aorta and iliac arteries in about one-third and to progression of the distal disease and technical factors, related both to the underlying disease and the operation employed, in the remainder. The most significant finding in patients with recurrent occlusion was the presence of a patent distal segment, permitting reoperation and restoration of normal pulsatile circulation in 48 cases (64 per cent).

#### **Occlusions of the Innominate, Carotid, Subclavian, and Vertebral Arteries**

Although multiple lesions are frequent, occlusive disease of the arteries supplying the head and upper extremities tends to assume 2 patterns of involvement: a proximal and distal form, similar to those observed in patients with arterial insufficiency of the lower extremities. In the proximal type, the occlusive process is located in the innominate, left common carotid, and left subclavian arteries. Although only 1 of these vessels may be involved, multiple involvement at this level occurs in the majority of instances. The obstruction may be incomplete and well localized or complete and extensive, involving a long segment. A fortunate characteristic of the lesions at this level is that a patent, accessible distal segment is always present, permitting operation. In the distal form of the disease, the occlusion may be located in the internal carotid artery near its origin, in the vertebral artery near its origin from the subclavian artery, or in both vessels. The occlusion can be incomplete and well localized, permitting restoration of normal circulation. Complete occlusions are usually extensive, involving the entire artery, and unless operation is performed early after complete occlusion, circulation is rarely restored by operative methods.

The most disabling symptom produced by these lesions is cerebral arterial insufficiency.

In a large number of patients studied because of these disturbances, 42 per cent had lesions located in the neck or chest as previously described. The clinical manifestations of arterial insufficiency vary with the location and extent of the lesion. The proximal lesions are associated with arterial insufficiency of the cerebrum and upper extremities. Pulses may be diminished or absent in the neck and arms, and the blood pressure may vary between the arms. Loud systolic murmurs may also be heard in the base of the neck and supraclavicular regions. The distal forms of the disease are associated primarily with attacks of cerebral arterial insufficiency which may be transient, apoplectic, or progressive in nature. Patients with occlusion of the internal carotid artery usually have contralateral motor and sensory disturbances, and homolateral, monocular visual symptoms. Occlusions of the vertebral arteries are associated with symptoms commonly ascribed to basilar artery thrombosis, namely, bilateral visual disturbances (cortical), vestibular dysfunction, cranial nerve defects, and bilateral motor and sensory disturbances. The arterial pulsations in the neck, throat, and face are usually normal in these cases. Although systolic murmurs may be heard in some patients, the lesion must be suspected mostly from the high incidence of extracranial involvement in patients with cerebral arterial insufficiency. The diagnosis is therefore made on suspicion and confirmed by performing the appropriate arteriographic procedures in all cases with these disturbances. In cases in which these neurologic disturbances develop acutely, this should be performed as an emergency. Arteriography, visualizing all the vessels of the upper extremities, the neck, and the head, has been performed in over 250 patients without significant complications, and the disease process was not made worse in any case.

Treatment in these cases is directed toward restoration of circulation to relieve symptoms and prevent progression of the disease. Two types of procedure may be employed for this purpose, endarterectomy and end-to-side bypass graft. Lesions of the great vessels arising on the aortic arch, being more extensive, are preferably treated by the bypass graft technic. The operable distal lesions are usually discrete and well localized and are preferably treated by endarterectomy. In the occasional case with more extensive distal lesions, the bypass graft may be a more suitable procedure. Cerebral protection during operation is required only in those cases with contralateral complete occlusions of the carotid artery. Temporary shunts may be conveniently and satisfactorily employed for this purpose.

During the past 6 years, we have employed this form of therapy in the treatment of 149 occlusive lesions occurring in 106 patients (Table







**Table IV**  
*Occlusive Disease of Innominate, Carotid,  
Subclavian, and Vertebral Arteries*

Location	No. of Lesions	No. Explored	Circulation Restored
Internal carotid	107	93 ( 87%)	80 ( 86%)
Common carotid	14	12 ( 85%)	12 (100%)
Innominate	15	14 ( 93%)	14 (100%)
Subclavian	23	21 ( 91%)	21 (100%)
Vertebral	15	9 ( 60%)	6 ( 66%)
Total	174	149 ( 85%)	133 ( 89%)

IV). A pulsatile circulation was restored in 133 lesions. The remaining lesions were complete occlusions of the internal carotid and vertebral arteries of long standing, no longer considered suitable for operation. Circulation was restored in all cases with lesions involving the great vessels, 97 per cent of those with operable lesions of the internal carotid artery, and 70 per cent of those with occlusions of the vertebral artery. All patients with lesions of the great vessels were completely relieved, and the majority of patients with distal lesions were either relieved or improved. These patients have been followed for periods of over 5 years, and the success achieved by operation has been well maintained, with recurrence in only 3 patients.

#### Occlusions of the Renal Artery

Atherosclerotic occlusion of the renal artery occurs in the same age group as described for other lesions of this type, and can be associated with hypertension. In the absence of other causes, hypertension appearing in this age group suggests the possibility of renal artery occlusion, particularly in the presence of other occlusive lesions. The atherosclerotic occlusive lesion in these cases is usually located near the origin of the renal arteries involving only a few centimeters of the vessel wall with a relatively normal, patent lumen distally. The lesion may be unilateral or bilateral and may be incomplete or complete, depending upon the stage of development. The hypertension associated with this lesion is believed to be produced on the same basis as that produced experimentally by Goldblatt and his co-workers.\* The diagnosis is made by aortography, permitting visualization of the renal arteries and the precise location and extent of the occlusive lesion.

Treatment in these cases is directed toward relief of hypertension; the method employed depends upon whether the lesion has produced

incomplete or complete occlusion. In the former case, treatment is directed toward restoration of normal blood flow to the kidney by means of endarterectomy or a bypass graft. In the latter instance, nephrectomy must be performed. Of interest is the fact that some patients with this disease have occlusive lesions involving both the renal arteries and the terminal abdominal aorta. In such cases, the bypass graft has been found particularly effective in restoring normal circulation to both the kidneys and the lower extremities. Results of these methods of treatment have been most gratifying, with relief of hypertension in all cases.

#### SUMMARY

1. In recent years, considerable progress has been made in the development of effective surgical treatment for aneurysms and atherosclerotic occlusive disease of the aorta and major peripheral arteries. Underlying this development are the principles of blood vessel suture and arterial graft replacement and the concept of localization or segmental involvement of the lesion. On this basis, several methods of surgical treatment have been developed which may be employed in accordance with the nature of the lesion to provide restoration of normal circulation. These reports are concerned with some of the more significant observations derived from an analysis of our experience with these methods of treatment in approximately 2,500 cases during the past decade.

2. For aneurysmal disease, treatment consists in extirpation of the lesion with restoration of normal vascular continuity and function. From a technical standpoint, this method of therapy may now be applied to all forms of aneurysms of the aorta and major peripheral arteries so long as the most proximal portion of the ascending aorta is uninvolved. The most important contraindications to operation are concerned with serious associated systemic disease or disabling cardiac, renal, or cerebral disturbances. The most important factors influencing the risk of operation are advanced age, pre-existing heart disease, hypertension, and rupture of the aneurysm.

3. Although atherosclerotic occlusive disease may be variable in its pathologic features, it tends to assume certain recognizable patterns, particularly as to location and extent of the occlusive process. Among these, the most important and the most frequently encountered are those involving the aorto-iliac region and femoro-popliteal region, resulting in arterial insufficiency of the lower extremities; the renal arteries producing hypertension; and the great vessels arising from the aortic arch causing arterial insufficiency of the brain and the upper extremities. Particularly important is the concept that in all of these patterns of involvement, the atherosclerotic occlusive process is frequently

\* J. Exper. Med. 59:347, 1934.

well localized and segmental in nature, with a relatively normal patent lumen proximal and distal to the lesion. The significance of this is that it permits the application of surgical treatment designed to restore normal circulation by means of 3 basic procedures: thromboendarterectomy, excision and graft replacement and the bypass graft principle. The successful application of these methods of treatment depends, in large measure, upon the nature and location of the lesion as determined precisely by arteriography.

Both immediate and long-term results have been highly gratifying.

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